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NAHBE I-TRUCK UTILITY 1/4 TON 4X4 M 151-A. RETROFITTING IMPLEME--ETC(U)
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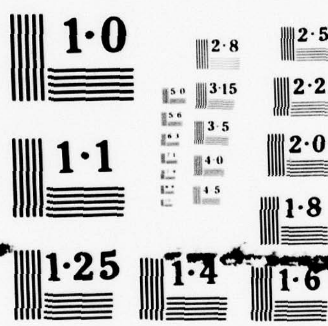
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LEVEL II

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U.S. Naval Academy
NAHBE Laboratory
Multicylinder Engine Program
NAHBE I
Truck Utility ¼ Ton
4X4 M 151-A
Retrofitting Implementation Feasibility Research & Development

Richard F. Blaser
1976-1977

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Fuel Availability
Fuel Supply System

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

"NAHBE I" is the first operative vehicle where the engine has been modified for achieving the basic performance of the Naval Academy Heat Balanced Engine concept.

"NAHBE I" started as a 1965 junked jeep. The engine had been used well over 30,000 miles. It was converted to the NAHBE geometry with two days of labor. Only the pistons, rings and gaskets were replaced. The timing and all the auxiliary hardware remain standard. The NAHBE uses no antipollution devices and has no driving limitations. It has been operated over 3000 miles of ordinary use.

406 923

JOB

From the certified results of test in the laboratories of the General Environmental Corp of Springfield, Virginia, the 7 grams per mile of NAHBE I, operated following the approved commuter pattern, are well below the 15 grams per mile maximum established by the current government standards. The matching of its emission with those from 1977 cars with all their sophisticated controls is a clear example of what creativity in the application of sciences can do for solving problems of our society. Furthermore, the bonus of its mechanical simplicity, its multifuel capabilities, its reduced peak pressures and temperatures and the natural completeness of its combustion are opening a field of positive economic and technical expectations.

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BACKGROUND

This project for proving the applicability of the NAHBE mode of operation in multi-cylinder, spark-ignited automobile engines was launched in July 1976, after intensive testing efforts on a mono-cylinder CFR engine have proven the operation feasibility of the NAHBE concept and the evaluation of the results have consolidated the expectations of its application for the refining of the internal combustion engines (see Report USNA EW No. 8 – 76). Because of the availability of vehicles and engines in the surplus pile of nearby Fort Meade, the *Truck–Utility* 1/4 Ton 4 x 4 M 151 was selected as the most expeditive and economic experimental specimen to be used on this phase of the feasibility research and development of the NAHBE concept.

Two jeeps and spare engines all with an average of 30,000 miles of operation were selected. After several iterations on the retrofitting, dynamometer evaluations, and operative road testings, the endeavor has crystalized in a fully operative vehicle which characteristics excel the most optimistic expectations.

This first member of the family of NAHBE is the starting of a fruitful technologic endeavor for the consolidation of realistic expectations in the improvement of the irreplaceable reciprocating Internal Combustion Engines.

This report outlines the creative efforts and the optimistic expectations open for *our* NAHBE I.

Richard F. Blaser
U. S. Naval Academy
Sept. 1977

SCOPE OF THE WORK

The soundness of the foundations of the NAHBE technology, reinforced by the outstanding results of the testing, the optical comparison of the combustions in the transparent engines, the successful operation of a 4 cylinder 1938 jeep engine converted to the NAHBE geometry with rivited exchange caps have proven that the theoretical expectations of the heat balanced cycle concept were operatively feasible.

From there, the retrofitting of an operative vehicle and the evaluation and comparison of its operative characteristics was selected as the logical next step for the understanding and development of the NAHBE applicability.

Basically the effort aims have been focused in simplicity, reliability, and driveability.

The following constraints have been established:

- minimum requirements for modifications of the engine vehicle and hardware.
- use of the existing fuel supply, ignition, timing, and operation control systems and hardware.
- maintain the standard operative performances of the engine and vehicle.
- maintain driveability of the vehicle and no change on the driver operation requisites and functions.

TRUCK UTILITY 1/4 TON 4 x 4 — M 151

RETROFITTING IMPLEMENTATION

DESCRIPTION (TM 9-2320-218-20 P; 34; 34P)

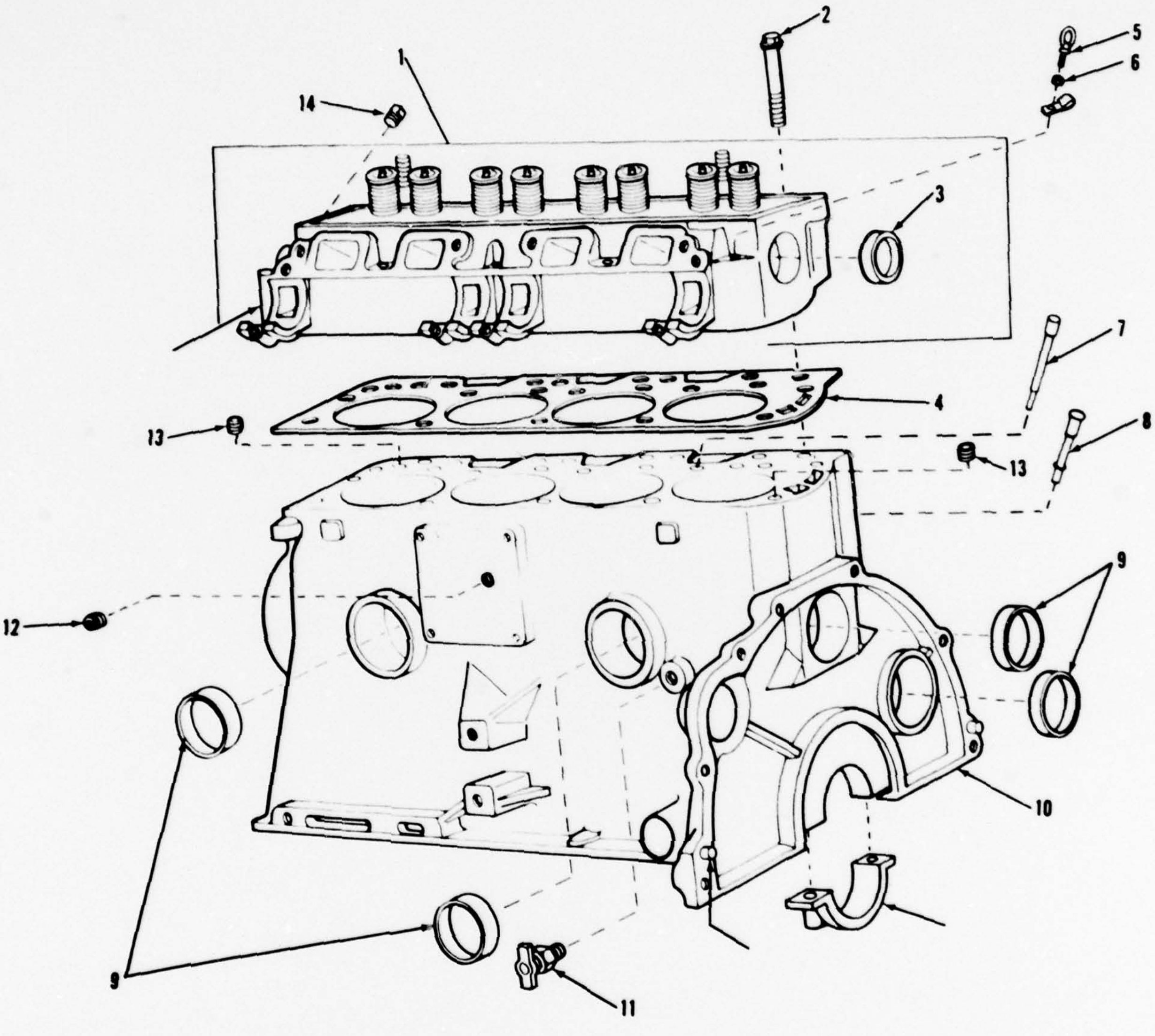
Utility truck, 4 x 4, 1/4 ton, right front view with top removed.

1. General Army Design
   4 Cyl. Int. Combustion
   Horse Power Rating
   71 HP at 4000 rpm at
   60°F. Air Temp—Torque
   128 lb. ft. at 1800 rpm
   Bore: 3.875 inch
   Stroke: 3.00 inch
   Disp: 141.5 cu. inch
   Cylinders: 4
   Firing Order: 1-3-4-2

2. Valve Arrangement:
   Overhead

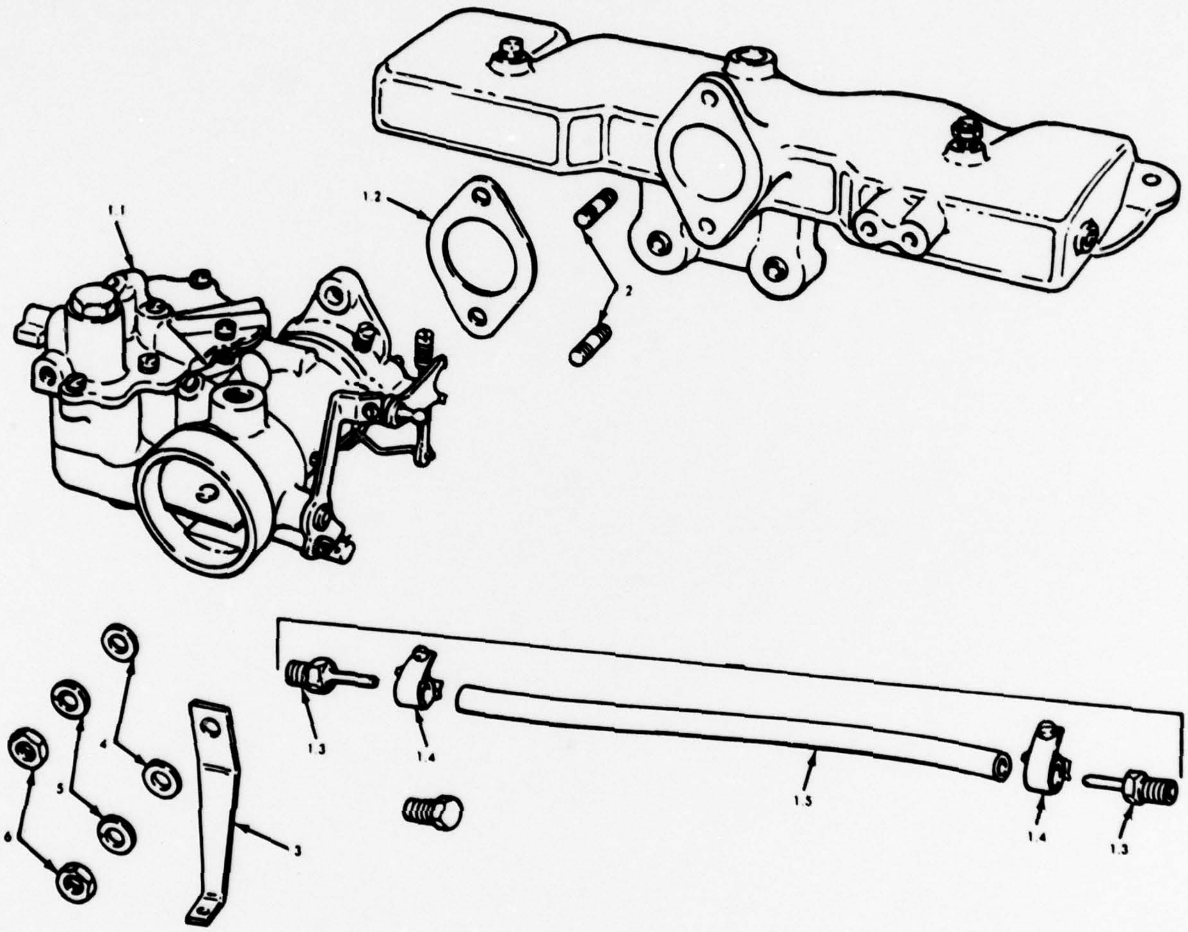
3. Valve Clearance:
   Intake: 0.015 inch
   Exhaust: 0.015 inch
   Comp. Ratio: 7.5-1
   Comp. at Cranking:
   135-145 psig
   (theoretical)

4. Weight:
   Power Plant: 528 lb
   Engine with Flywheel and
   Accessories—328 lbs.
   Engine with Flywheel and
   W/O Accessories: 257 lbs.
   Belts for Fan: 25 amp
   Generator and Water
   Pump: 2 "V" Wedge,
   0.38 Inch Wide x 33.0
   Inch Long
   Belts for Fan: 60 amp
   Alternator 3 "V" Wedge
   0.47 In. Wide x 35.25
   In. Long
   Windshield Washer Reservoir
   Cap.: 3 Qts.

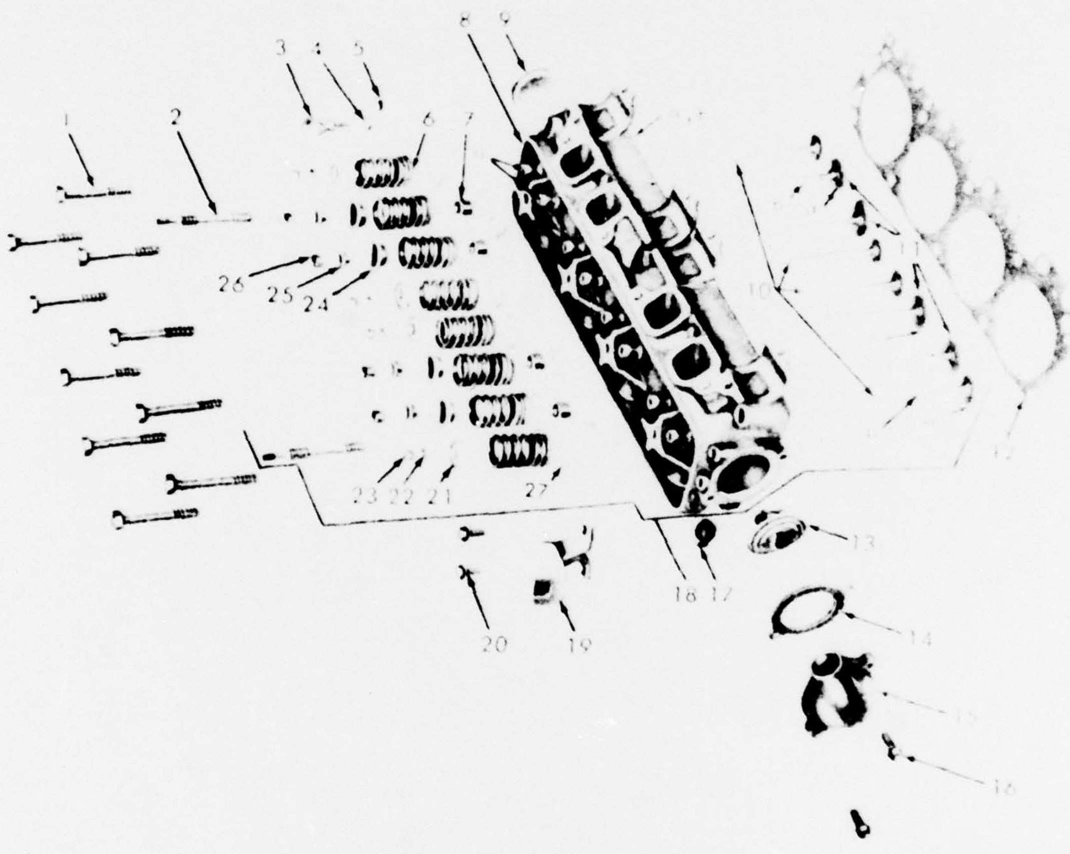


Engine block and cylinder head.

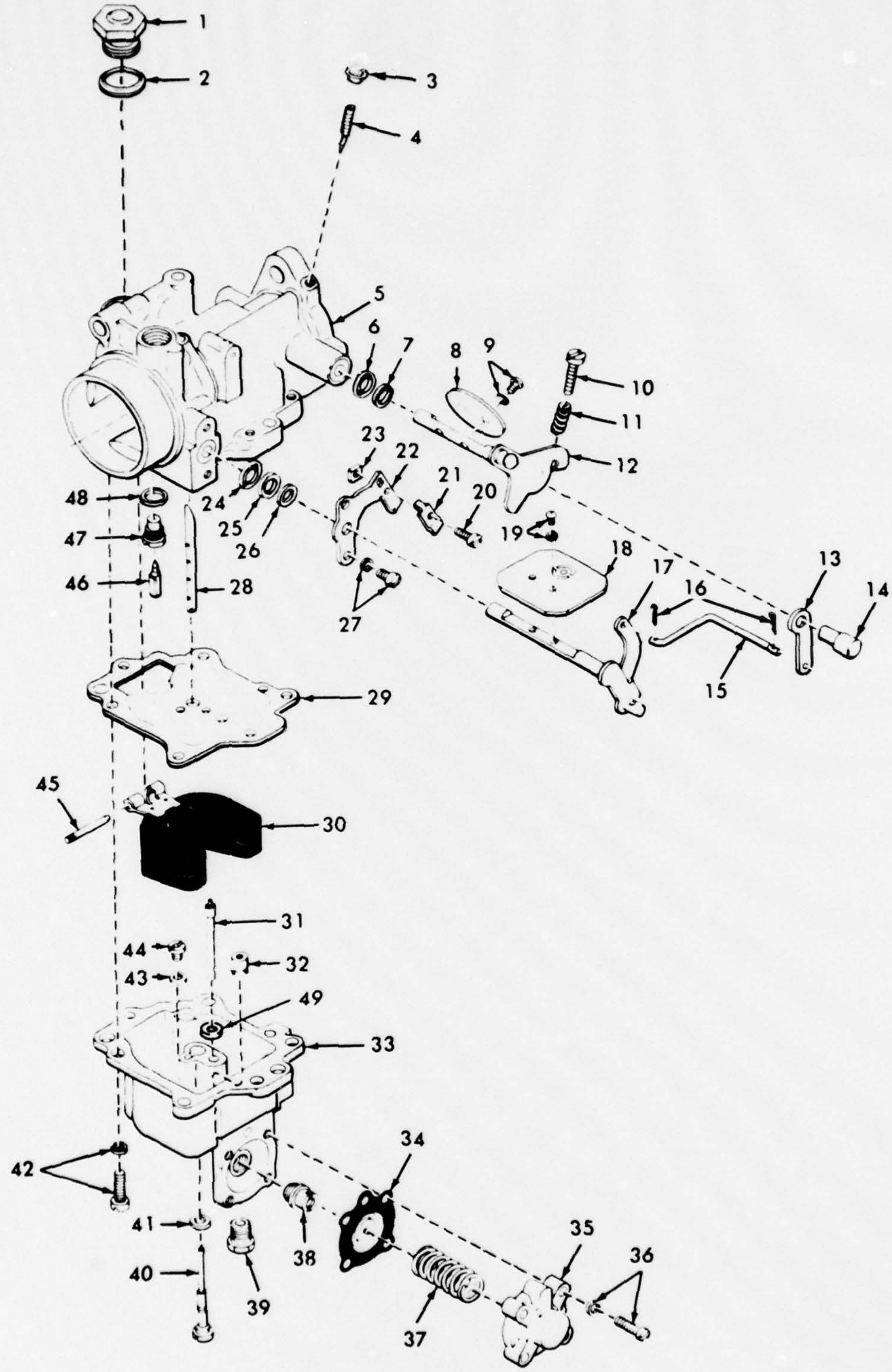
For complete identification of all components, see parts manual.



Carburetor assembly and related parts.



Cylinder head, valves and related parts—exploded view.



Carburetor assemblies (Zenith 10939511 and 11641105).

NAHBE I – ¼ TON TRUCK, UTILITY, 4 x 4, M – 151, RETROFITTING IMPLEMENTATION

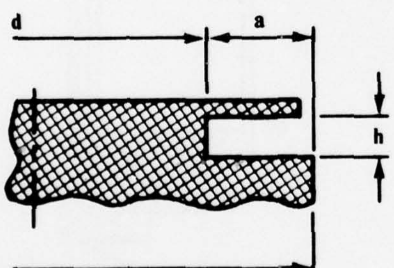
NAHBE GEOMETRY

The constraints of the scope of the work preclude any optimization in the geometry considerations. The most simple symmetric geometry, similar to the one used on the CFR engine was selected and the design effort was focused in machining and assembly simplicity.

NAHBE I final geometry with more than 5,000 miles of operation and the modification of a standard surplus engine accomplished in two days work of two unskilled mechanics replacing only piston rings and gaskets, are the corroborating factors of the retrofitting feasibility. (See photos)

PARAMETRIC EVALUATION

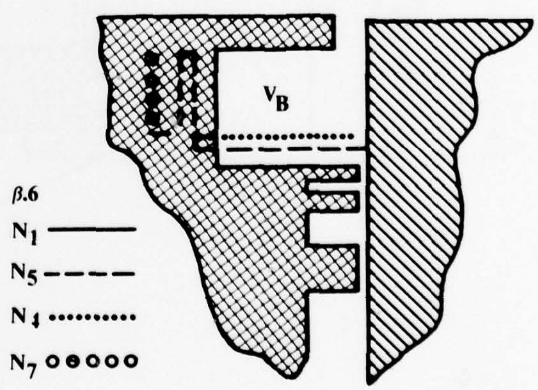
Number	1	2	3	4	5	6	7
d	2.875	2.975	3.075	2.675	2.775	2.575	2.475
S	11.79	11.79	11.79	11.79	11.79	11.79	11.79
β	6.49	6.95	7.43	5.62	6.05	5.21	4.81
Δs	5.30	4.84	4.36	6.17	5.74	6.58	6.98
h1	.342	.375	.416	.294	.316	.275	.259
h2	.385	.421	.468	.330	.355	.3100	.292
a	.500	.450	.400	.600	.550	.650	.70



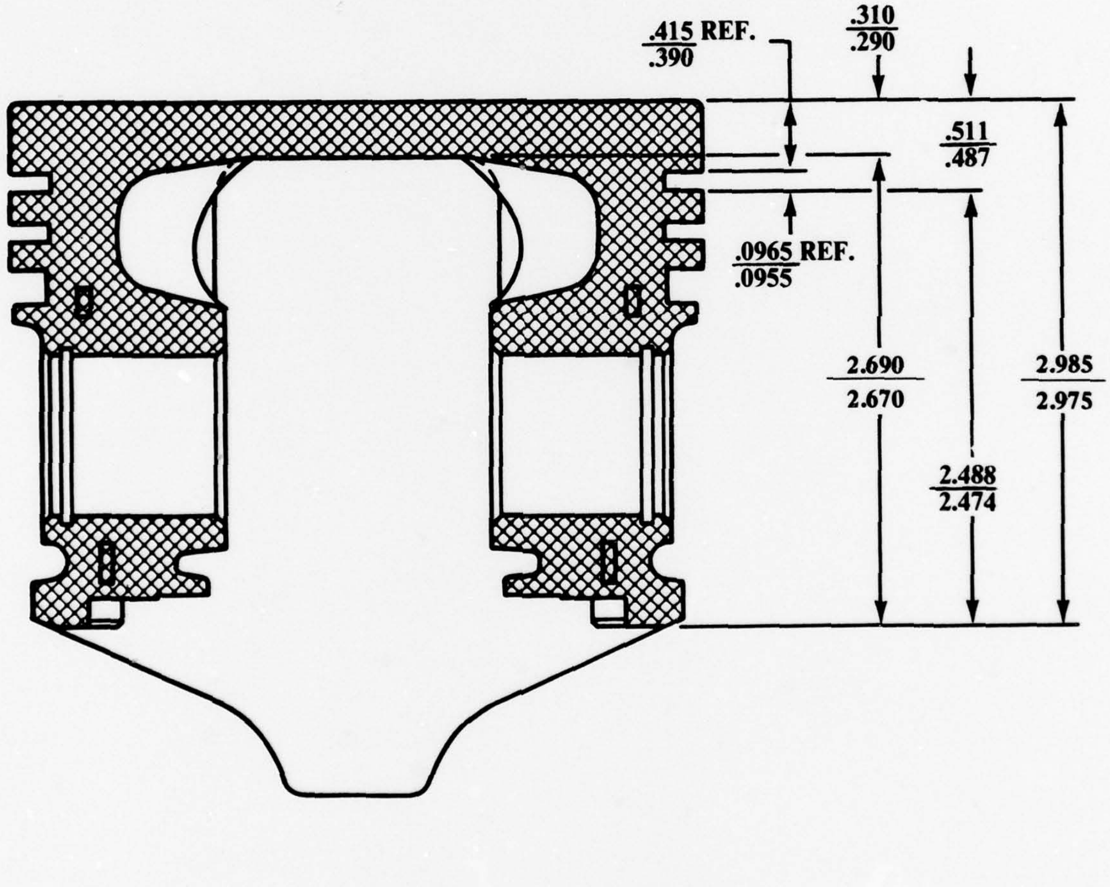
SELECTED APPROACH

$\beta = .5$ $\quad V_A = 3.63$ $\quad V_C = 5.44$

$r = 7.5{:}1$ $\quad V_B = 1.81$ $\quad V \approx 35.38$

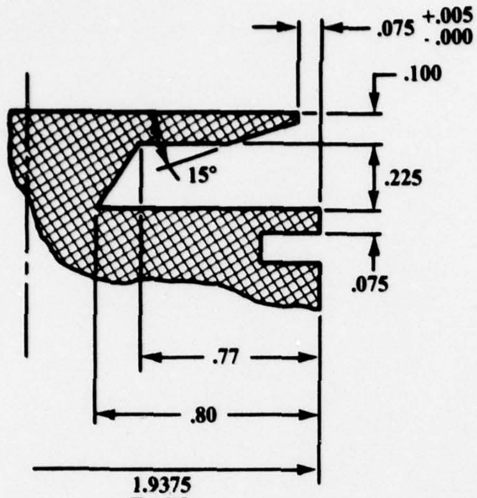


DIMENSIONING AND MODIFICATION



ACTUAL PISTON GEOMETRY

PISTON MODIFICATION *(FIRST ITERATION OF THREE)*



$V_B = 1.70$

VOLUME V_B

1 

V1 = 1.738

D = 3.875 s = 11.79
d = 2.275 s = 4.06
Δs = 7.22
h = .225

2 

V2 ≈ .258
V1 - V2 = 1.480

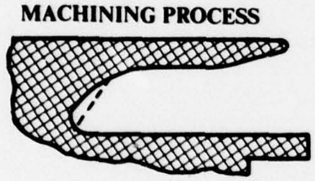
D_s = 2.575 s = 5.207
^{D}s = 1.148

3 

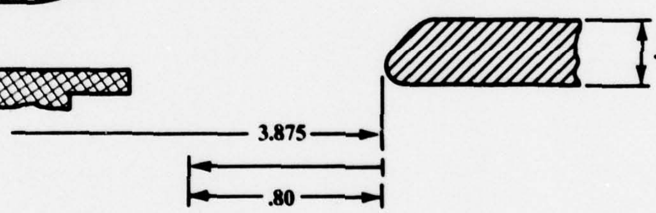
V3 = VT-VS
V3 = .208

D = 3.875 S = 11.79
h = .100 VT = 1.175
d = 3.128 s = 7.58
vs = .996

MACHINING PROCESS



SHAPED TOOL



1. FROM A CONTROLLED DISTANCE 1.9375 OF THE CENTER LINE MACHINE .80 DEEP GROOVE AT .075 OF THE UPPER RING GROOVE.

2. WITH THE TIP OF A CUTTING TOOL AT 1.4375 OF THE CENTER LINE AND .100 OF THE GROOVE CUT THE 15° TIP.

3. WITH THE TOOL AT 1.4375 OF THE CENTER LINE ADVANCE CUTTING THE TIP .075 $^{+.005}_{-.000}$

4. DEBURR SHARP EDGES

4281 $\frac{1689}{.1604}$ 1655

HEAD MODIFICATION

SHAVING OPERATION FOR r = 7.5:1

METAL REMOVED h = .155

SECOND ITERATION

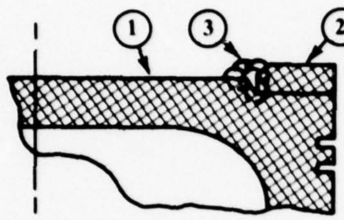
DYNAMOMETER TESTING

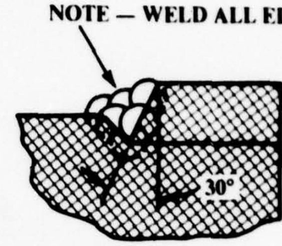
PISTON AND SUPPLEMENT MACHINING AND ASSEMBLY

(1) STANDARD PISTON

(2) SUPPLEMENT

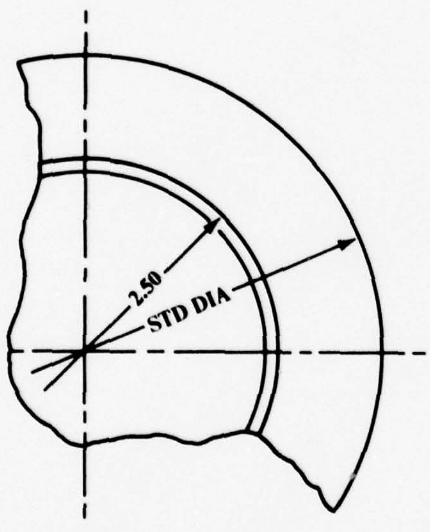
(3) WELDEMENT

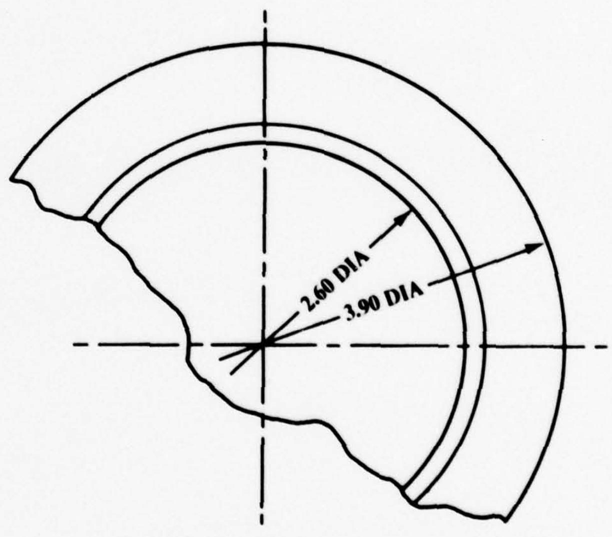


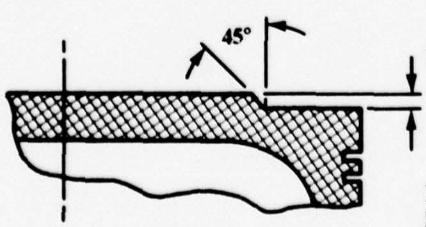


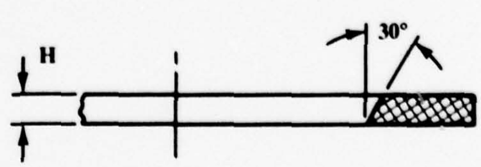
PREPARATION OF PISTON
MACHINING REQUIRED

PREPARATION OF
ADDITIONAL RING
TO BE ADDED TO PISTON



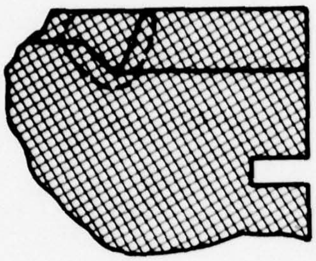






H = H - .100
H ≈ .250

V_B DESIGN — SELECTED APPROACH

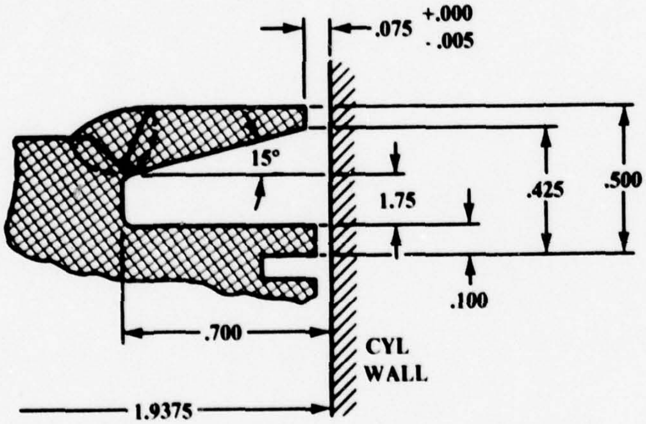


$V_B \neq 1.68$

$V_A \neq 3.245$

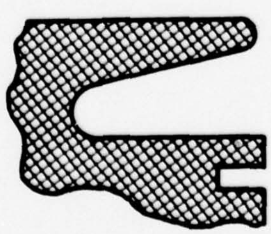
β .52

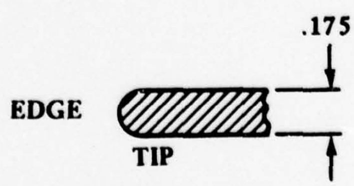
REF FIRST RING GROUP
CYL. WALL
1.9375 OF C/L



MACHINING FOR ITERATION 2

Tool .175 with Tip – Round





NOTES

1) With TIP at 1.9375 of c/l and EDGE .100 of first ring grove advance .600 cutting groove on piston.
2) With tool cutting tip at 1.9375 of c/l and .425 of first ring groove cut the 15° face.

HEAD MODIFICATION REQUIRED

Bore each chamber 13.875 Dia. x .200 deep
Shave head (.085), for (r = 8:1)

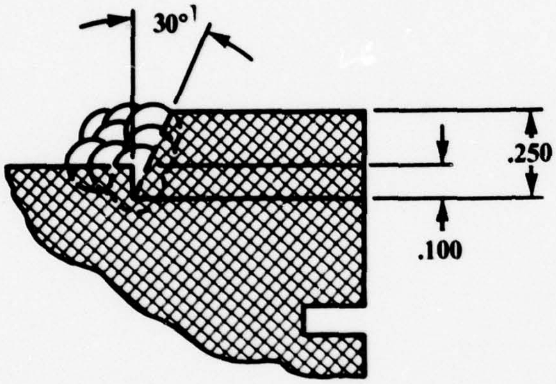
THIRD ITERATION

NAHBE I OPERATIVE IMPLEMENTATION

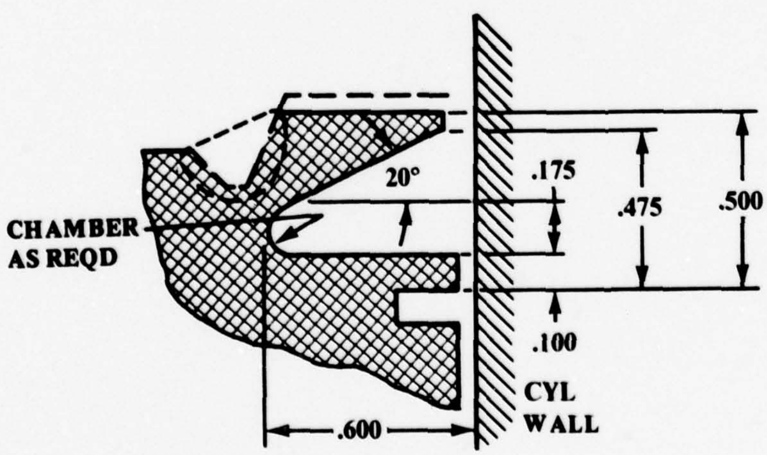
1/4 TON UTILITY TRUCK ENGINE

PISTON MODIFICATION. VEHICLE ENGINE.

GEOMETRY OPTIMIZATION.

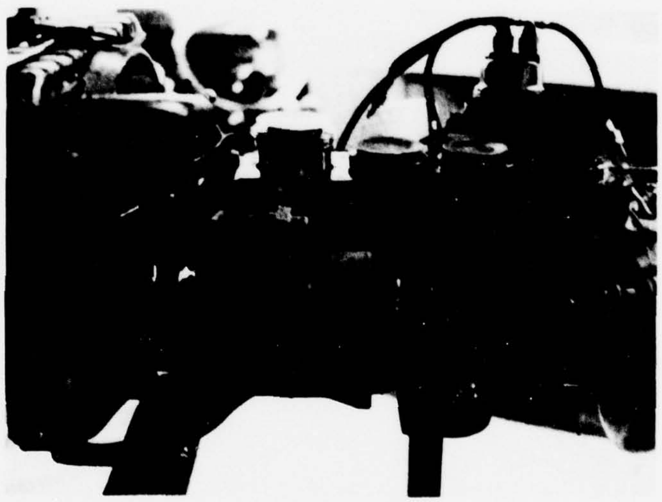


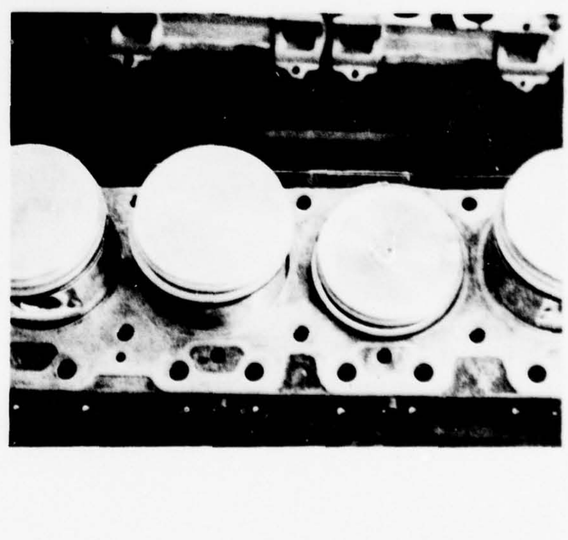
$V_B \cong 1.69$
SELECTED $r = 7{:}1$
$V_C = 5.896$
$V_\Delta \cong 4.226$
$\beta = V_B = .40$



HEAD MODIFICATION
BORE EACH CHAMBER 3.875 DIA || .200 DEP
SHAVE .050 FOR REQUIRED D r = 7:1r

Engine Retrofitting





NAHBE FUEL SUPPLY

The constraints of simplicity and use of existing fuel supply hardware, have limited the scope of alternatives. Moreover, the use of a standard carburator which function is to produce a homogeneous air-fuel mixture, have reduced to a minimum the optimization of the NAHBE mode of operation. The variable availability of oxygen required for the completeness of the NAHBE combustion process is greatly interferred by the carburetor characteristics.

THE FUELER

For achieving the NAHBE combustion, it is required that at the end of the compression stroke before ignition, most of the fuel should be in the main combustion chamber and the reserve of air for sustaining a variable availability of oxygen need to be in the balancing chamber or piston. Once over, it is convenient to emphasize that no combustion occurs in this air reservoir. When it is poisoned with fuel into flamability limits and combustion occurs, the NAHBE combustion process is seriously altered.

This division of the incoming charge of fuel and air can mot be sustained by a mass flow governing device as happens with the venturi in the carburetor.

The simplest fueling system uses a standard intake manifold, a bleed of air in the port for securing air at the beginning of the intake event and a needle valve for controlling the amount of fuel to be added to the main stream of air controlled by the throttle.

The general name of *Fueler* is proposed to clearly identify the fact that the constraints of its functions are completely unrelated to those of the carburetion or injection devices for the Otto and Diesel engines.

The *Fueler* for NAHBE can be implemented and optimized through the application of the state of the art technology and a family of mechanics, fluidics, and electronics devices, should offer their capabilities for the fulfillment of those specific requisites.

SELECTED APPROACH

The incompatibility of the Jeep carburetion system did not allow freedom for the fueler design. After trial and error was accepted that the capabilities for controlling the fuel supply over all the range of operation was impossible and, unavoidably; the use of the basic hardware requires the acceptance of operative compromises. The actual design with air boosters for better charge stratification and the fuel supply in carbureted mixture was accepted as the simplest approach.

Because, with the minimum possible supply of carbureted mixture the engine idle was over 3,000 RPM, an operative compromise was required. Two cylinders were knocked down by adding air through calibrated holes in their booster sufficiently to avoid flamability limits. The presence of

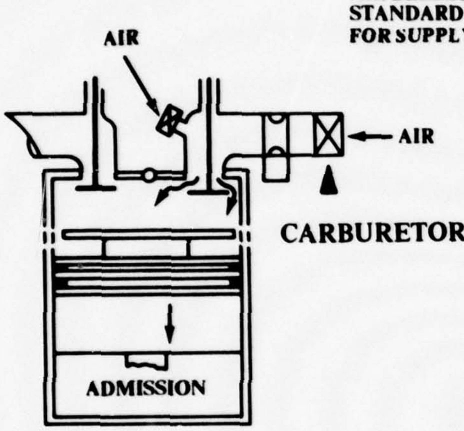
crude fuel in the exhaust gases at idle was accepted. After the operative evaluation of NAHBE I, Midshipman Brent Norman simplified the problem by including two butterfly valves for shut down of the air-fuel mixture to two cylinders during idling operation.

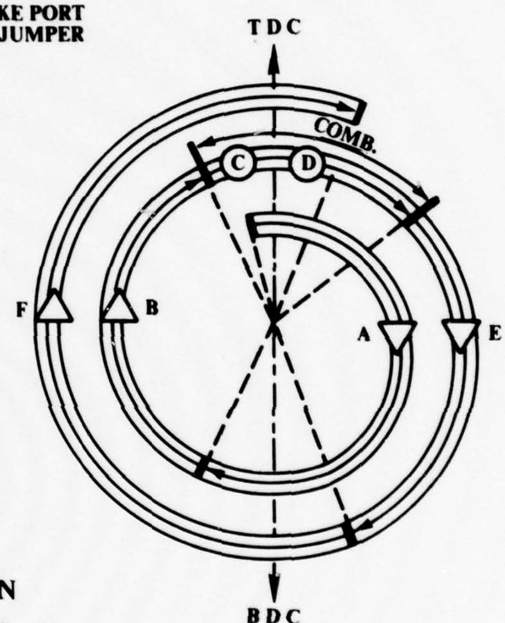
The first iteration with vacuum control action reduces the crude fuel in the exhaust more than 70% and his second approach using a solenoid actuator promises further better control.

FUEL SUPPLY DESIGN

SELECTED APPROACH

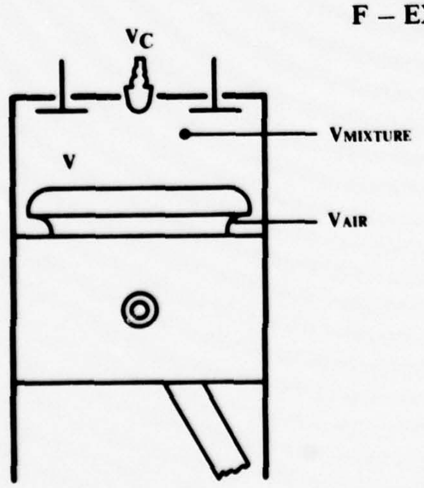
AIR BLEEDER IN INTAKE PORT
STANDARD VENTURY JUMPER
FOR SUPPLY OF FUEL





OPERATIVE TIMING

A – ADMISSION
B – COMPRESSION
C } COMBUSTION
D }
E – WORK
F – EXHAUST

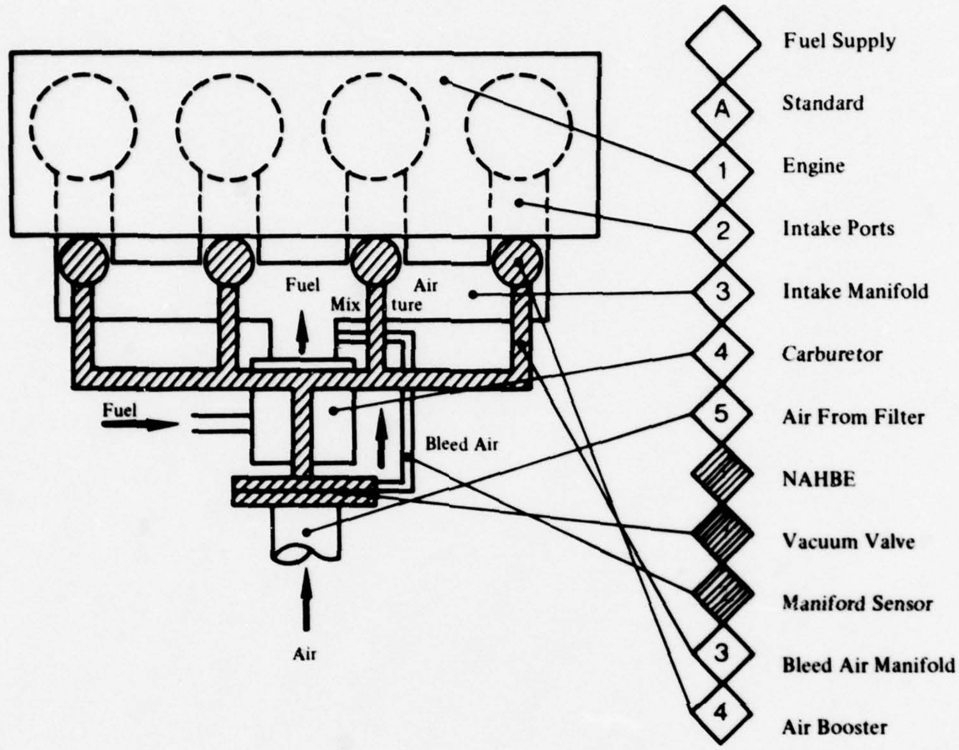


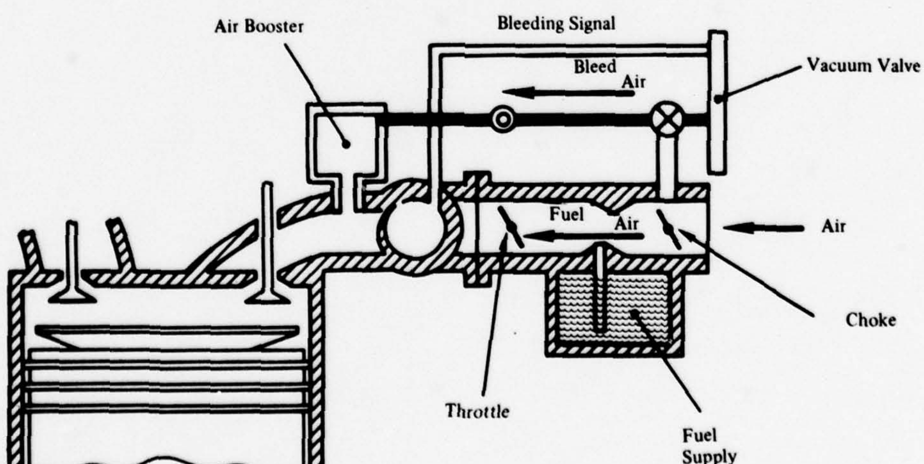
DIMENSIONING

$\beta = .4$ OR $1/3\ V_C$

$V + V_C = 41.27\ in^3$
$V_{AIR\,MAX} \cong 13.75\ in^3$

FUELER LAY OUT
BLEED AIR APPROACH

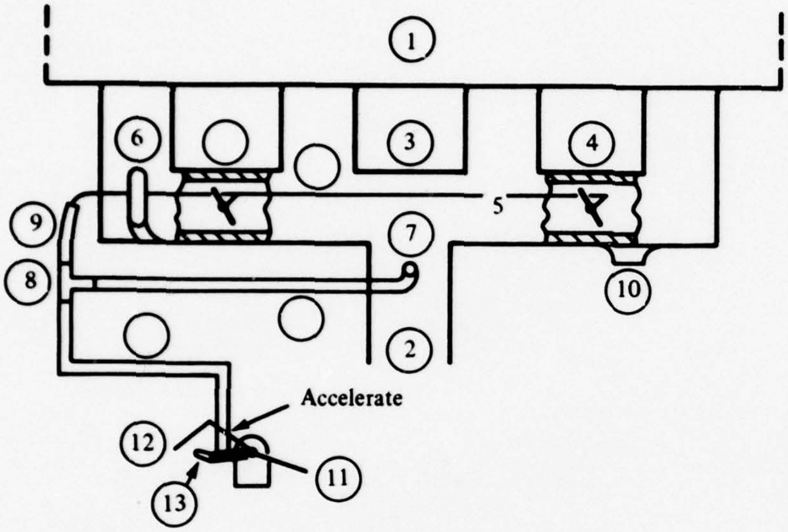




Note: The air booster volume will allow an availability of atmospheric air at the intake port enough for filling only air during the first 20° of the intake event.

FUELING SYSTEM CHANGES

MODIFICATION I TO MANIFOLD TO ALLOW TWO CYLINDERS TO BE SHUT OFF AT IDLE



1 Cylinder Block
2 Carburetor
3 Intake Manifold
4 Buttefly Valve
5 Rod
6 Vacuum controlled Diaphragm Acuator (VCDA)
7 Hole Placed in Intake Manifold
8 "T" Hose Connection
9 Hose
10 Accelerator Connection
11 Accelerator Cable
12 Connection to Carburetor
13 Bleeder Valve

Problem: At idle two cylinders were not firing due to too much air introduced. To get to idling RPM only two cylinders could be used. Because of this crude hydocarbons were being put into the exhaust.

Solution: Devise a system to cut off the gas and air supply to two cylinders at idle.

Process: Insert butterfly valves in line between cylinders 1 and 2, 3 and 4. Connect a rod between the two butterfly valves. Install a vacuum controlled diaphragm actuator to move the mechanical arms of the butterfly valves. To actuate (close two cylinders) the (VCDA) is connected by hose to a "T" hose connection. Place hose to connection on manifold and "T" connection. The manifold pressure will close the butterfly valves. A third hose is connected to the bleeder valve. During acceleration the bleeder valve is opened destroying the vacuum to the (VCDA) and the butterfly valves open allowing all four cylinders to have combustion.

Results: The idle was smoother, the HC level was reduced to 30% of the original NAHBE I operation. The use of a vacuum actuated system was that at high RPM's the manifold vacuum increased causing sufficient vacuum too.

Force the butterfly valves to partially or completely close. This caused rough running, reduced speed, and overheating. To eleviate the vacuum problem an electrical solenoid will be used. A switch will be actuated by the accelerator as before.

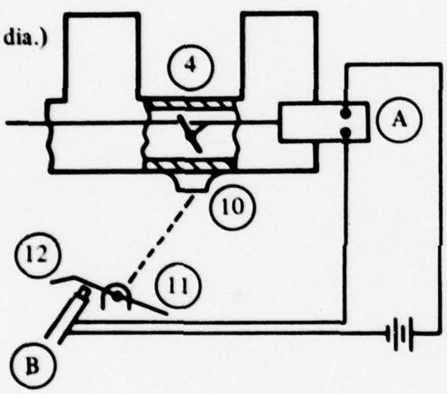
MODIFICATION II

Problem: Vacuum system is not accurate nor reliable.

Solution: Replace vacuum with a electro-mechanical system.

Process: Plug ⟩ hole in manifold. Take off components 6, 9, 8, 13.

(See front dia.)



A Electrically actuated-mechanical movement solenoid 24 v.

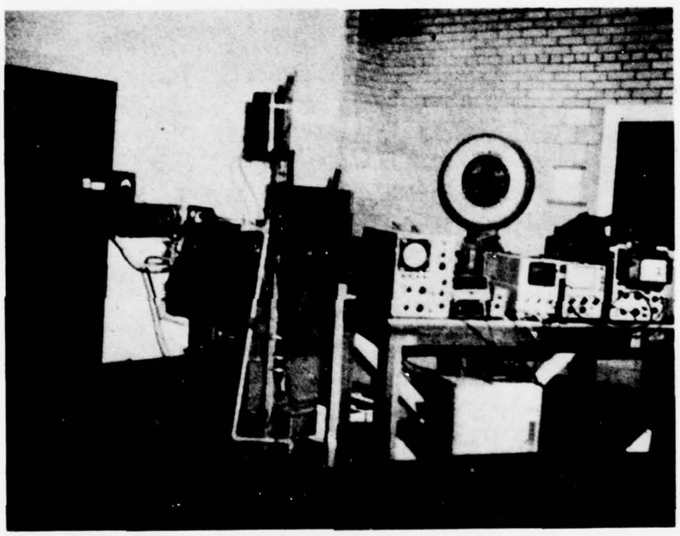
B Switch

The switch position may be adjusted to accurately control the opening and closing of the butterfly valves.

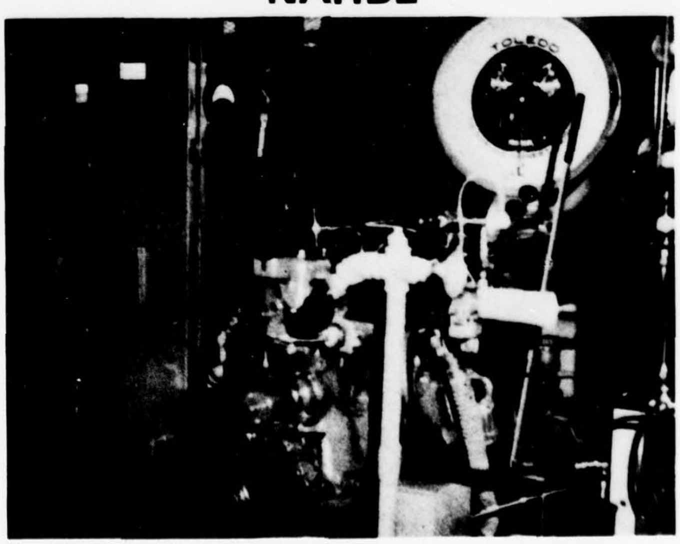
NAHBE I

Dynamometer and Road Testing
Dynamometer Set-Up

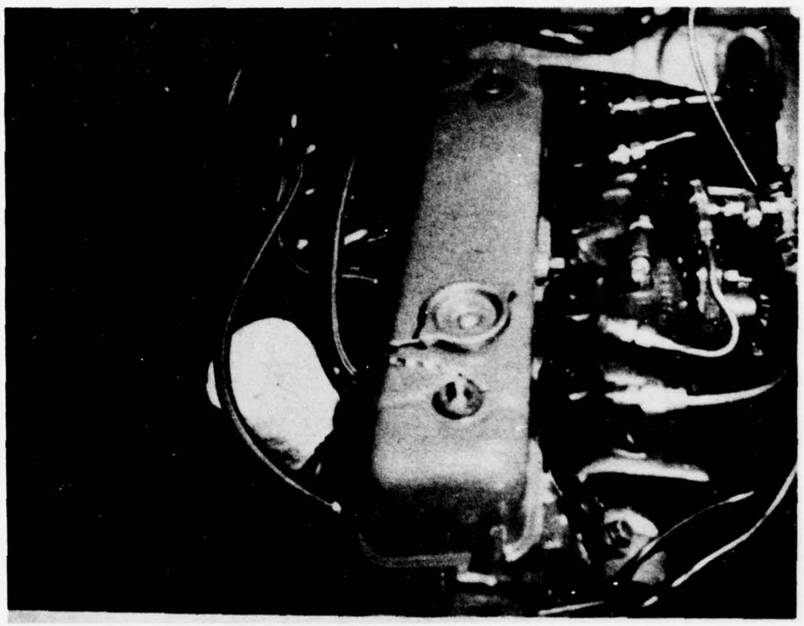
Standard

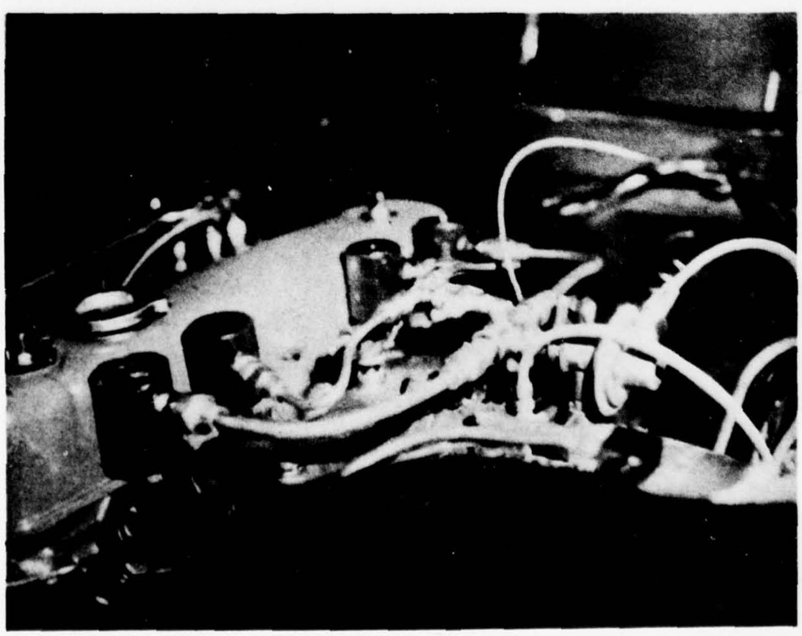


NAHBE



Vehicle - Set-Up





EVALUATION

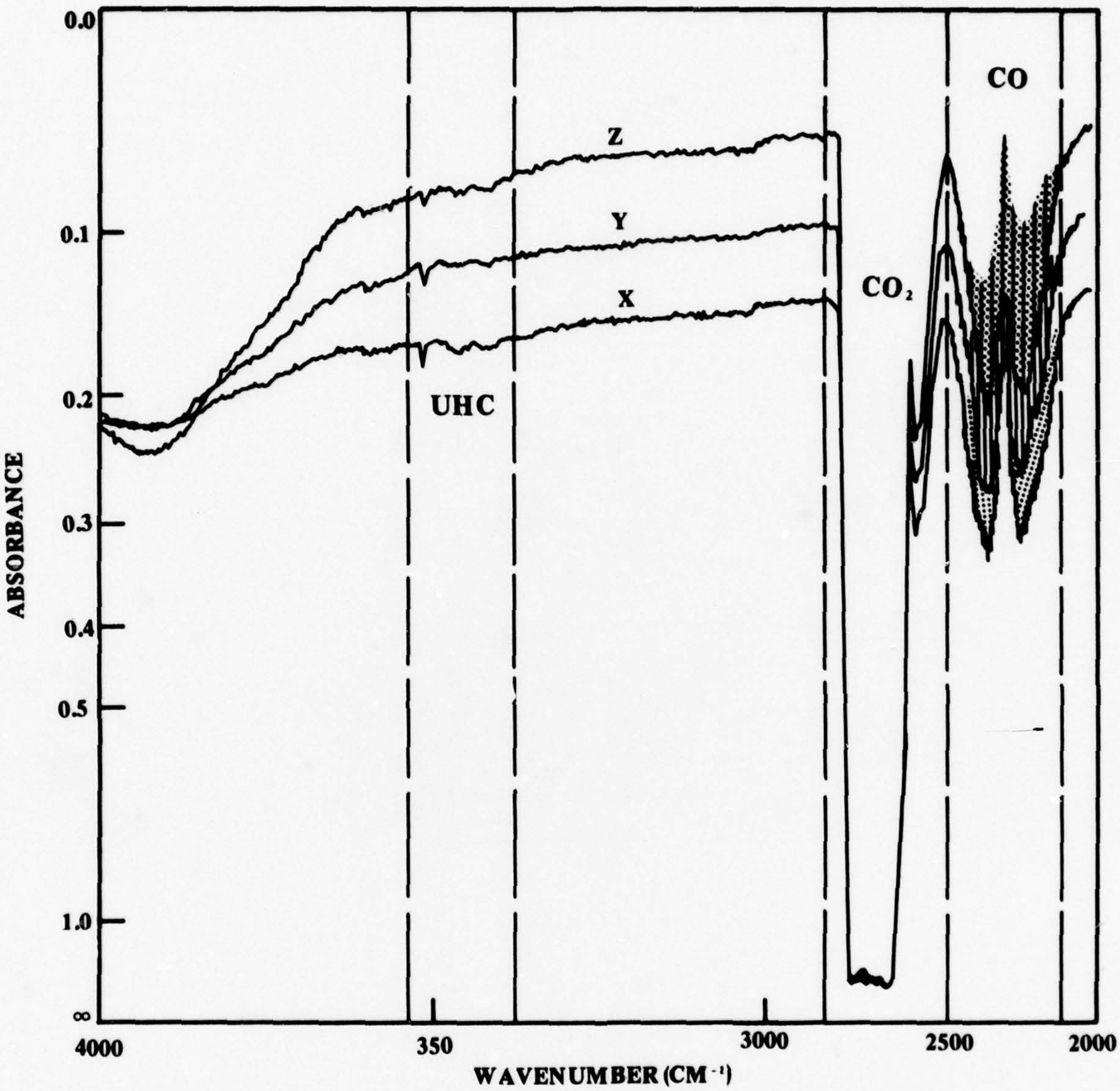
During a period of more than three months an intensive program of dynamometric and road testing was performed.

The acquisition of compatible operative data on laboratory testing and the driveability analysis of similar road testing supplied the information required for a fair comparison between the characteristics of the standard NAHBE operation and those of one operating in NAHBE mode.

NAHBE I exceeds the standard in acceleration, torque and output. In the ranges of operation the CO in the exhaust gases is minimum and the absence of Methane (CH_4) shows that the detected unburned hydrocarbon (UCH) are not products of an incomplete combustion but crude fuel accepted for idling.

STANDARD JEEP

EXHAUST GAS ANALYSIS



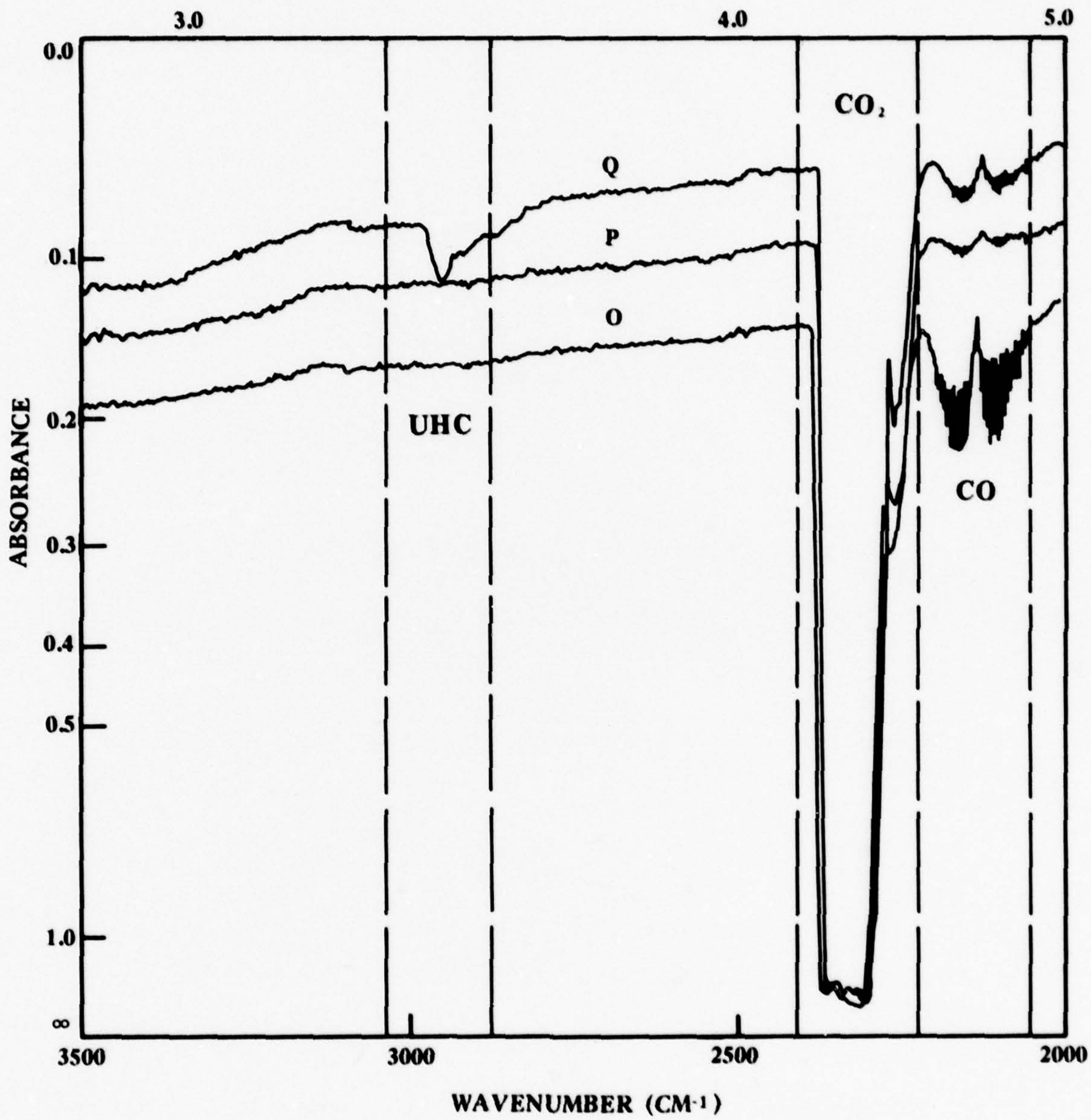
X HIGHWAY DRIVING – STOP 1st-2nd-3rd-4th TO 50 m/hr

Y FULL THROTTLING – 4th TO 58 m/hr

Z ACCELERATION – STOP 1st-2nd-3rd-4th TO 40 m/hr

NAHBE I

EXHAUST GAS ANALYSIS



Q HIGHWAY DRIVING – STOP 1st-2nd-3rd-4th TO 50m/hr

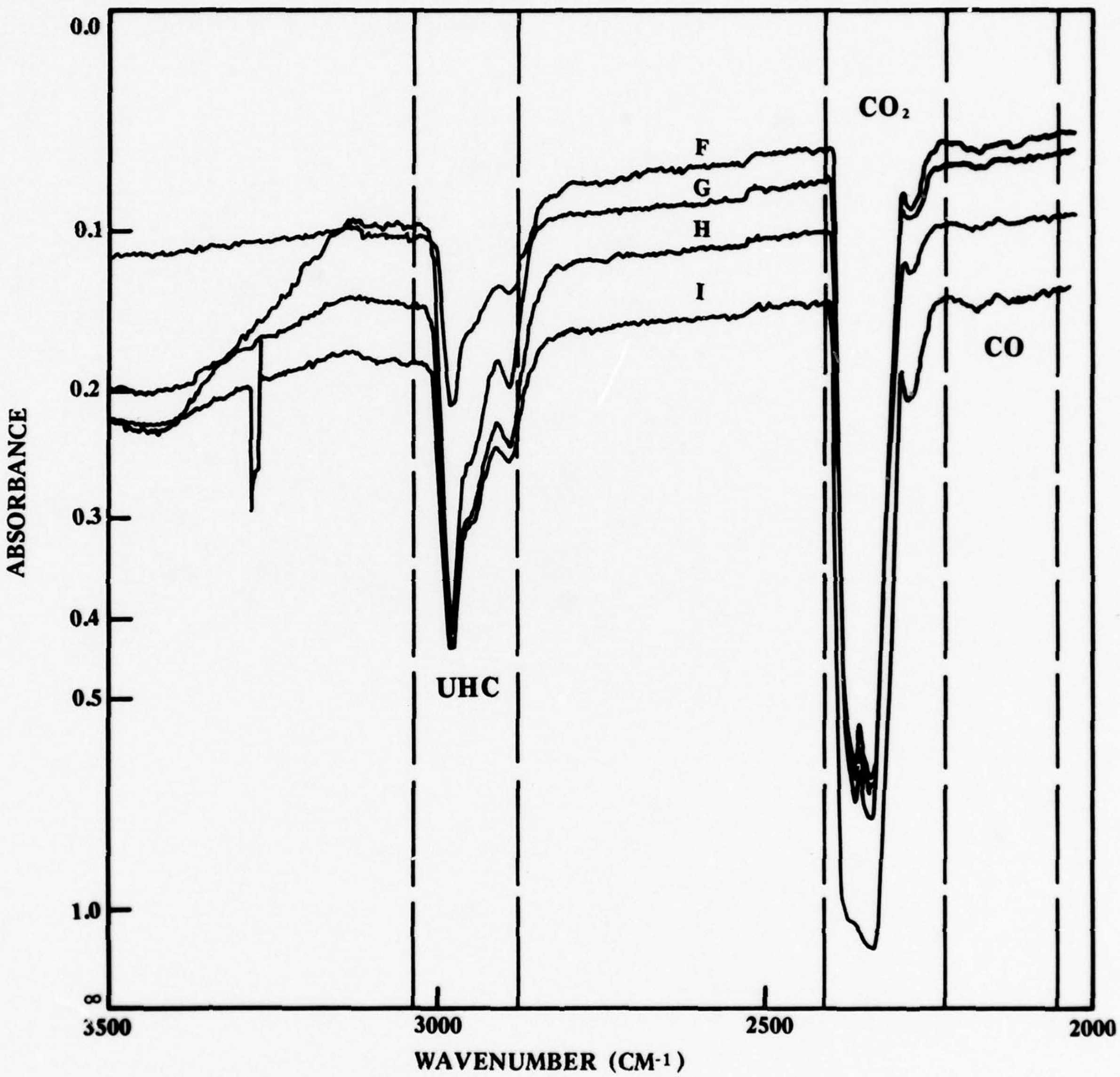
P FULL THROTTLING 4th TO 62 m/hr

O ACCELERATION STOP 1st-2nd-3rd-4th TO 40 m/hr

NAHBE I

EXHAUST GAS ANALYSIS

Idle Iteration



F LOW RPM IDLE-EXHAUST PORT

G LOW RPM IDLE-TAILPIPE

H STANDARD IDLE

I HIGH–RPM IDLE

NAHBE I – EPA CERTIFICATION

Although the ¼ ton truck, M 151 was not designed for stop and go performance and the idling compromise of NAHBE I affects the results of driving patterns of stop and go accelerations; the three bag exhaust analysis of the commuter and highway exhaust gases and fuel ecomomy testing procedures of EPA were selected as definitive independent sources of information for the evaluation of the applicability of the NAHBE mode of operation to multicylinder (S.1.) vehicle engines.

In September, 1976 a standard jeep was sent to the certified laboratories of General Environment Corporation of Springfield, Virginia, and in January, 1977 NAHBE I was tested following the same EPA approved schedule in use for standard automobiles. The completeness of the NAHBE combustion process was reflected in the 7 grams per mile of CO – well below the maximum of 15 grams per mile maximum accepted by EPA.

A second test was performed on NAHBE I, adjusting the idling to 2,500 RPM. The unburned hydrocarbons in the exhaust come down from 41 to 9 grams per mile with CO and NOx within specified EPA limits. Those results confirm that a fully optimized *Fueler* without the constraints of the project should reduce UHC below 100 ppm as obtained in previous tests.

Considering that the crude fuel in the exhaust should be normally controlled or burned by using a suitable *Fueler*, the following correcting equation has been used:

$$MG_C = .98 \ \frac{2896 \ MG_T}{2896 - HC_T \times MG_T}$$

MG_C – Corrected mile per gallon

MG_T – Test mile per gallon

HC_T – Test hydrocarbons in grams per mile

2896 – grams in a gallon of fuel

.98 – correcting factor for UHC in normal NAHBE conbustion process

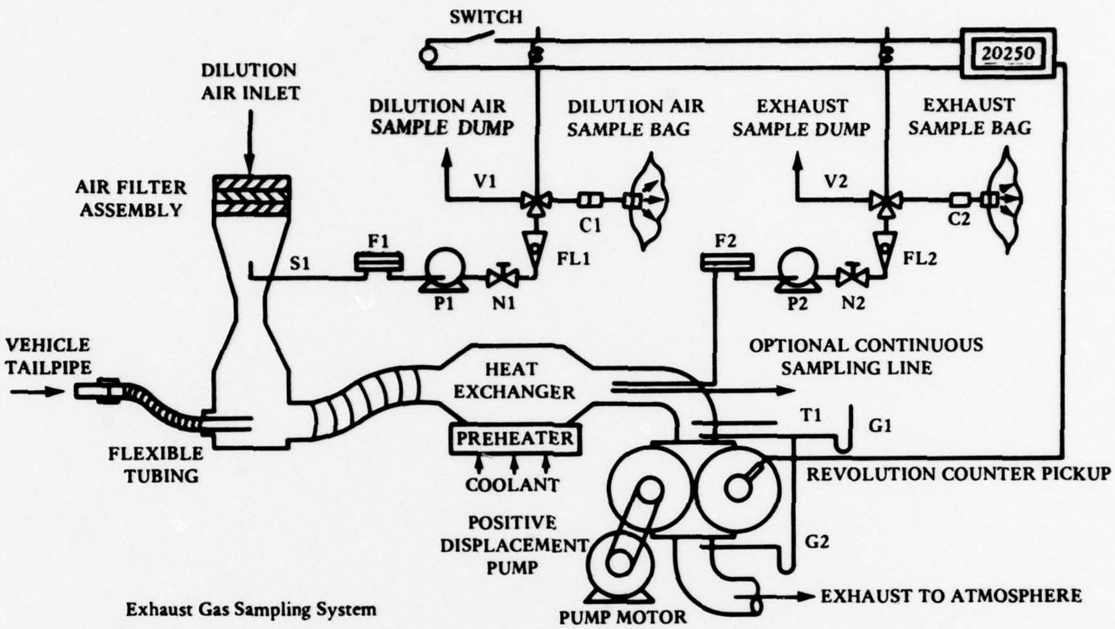
The corrected values are:

	Test 1 (436)*	Test 2 (440)
Commuter	21.89	17.60**
Highway	25.92	26.33

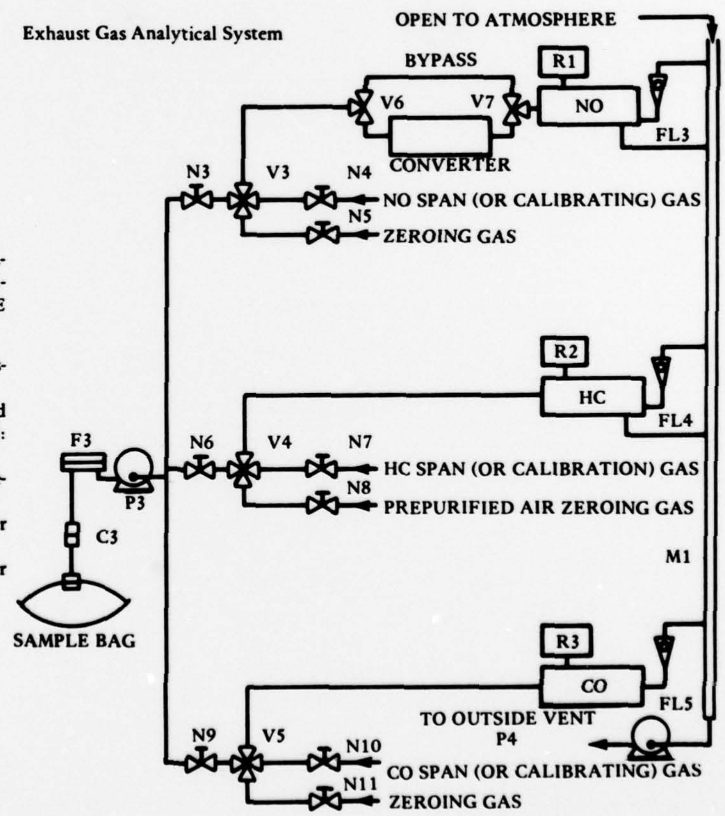
* Used for comparison
** Due to idling at 2,500 RPM, the consumption during the stop in the driving pattern increased.

EPA CERTIFICATION INFORMATION

EXHAUST EMISSION STANDARDS AND TEST PROCEDURES



Exhaust Gas Sampling System



Exhaust Gas Analytical System

Title 45—PUBLIC WELFARE

Chapter XII—Environmental Protection Agency

PART 1201—CONTROL OF AIR POLLUTION FROM NEW MOTOR VEHICLES AND NEW MOTOR VEHICLE ENGINES

§ 1201.21 Standards for exhaust emissions.

(a) Exhaust emissions from 1972 and 1974 model year vehicles shall not exceed: Int. 1975-76.

(1) Hydrocarbons—1.5 grams per vehicle mile.

(2) Carbon monoxide—15. grams per vehicle mile.

(3) Oxides of nitrogen 3.1 grams per vehicle mile.

NAHBE I
COMMUTER CYCLE
Test 1

GENERAL ENVIRONMENTS CORPORATION
THREE BAG EXHAUST EMISSIONS ANALYSIS

VEHICLE NUMBER: 5332 DATE: (M, D, Y): 1 19 77
RUN NUMBER: 438 TEST SEQUENCE NUMBER: 1

HUMIDITY CORRECTION FACTOR AND PERCENT RELATIVE HUMIDITY

PART	BARO	KH	R
1	29.64	.787014	15.1807
2	29.64	.782265	13.0986
3	29.63	.783626	13.7138

GRAMS PER TEST PHASE

PART	HC	CO	CO_2	NOX	NOXC
1	88.83	39.88	1479.84	16.08	12.66
2	205.78	23.56	1495.95	9	7.04
3	111.57	25.02	1270.57	11.79	9.24

1975 MASS EMISSIONS IN GRAMS PER MILE

HC	CO	CO_2	NOX	NOXC
41.01	7.33	380.87	3.02	2.37

1975 CALCULATED FUEL ECONOMY: 16.99 MPG
READY

NAHBE I
TEST 1

GENERAL ENVIRONMENTS CORPORATION
HIGHWAY FUEL ECONOMY ANALYSIS

VEHICLE NUMBER: 5332
RUN NUMBER: 438

DATE (M, D, Y): 1 19 77
TEST SEQUENCE NUMBER: 1

INPUT DATA FEEDBACK

DELTA P	INDEP	REVS	TEMP
93.6	79.56	17738	116

BARO	WET BULB	DRY BULB
29.63	50.1	77.05

SAMPLE BAG:

	HC	CO	CO_2	NOX
DIVISIONS	67.3	50.7	39.9	59.6
CURVES	5	8	11	14

AIR BAG:

	HC	CO	CO_2	NOX
DIVISIONS	.6	.6	1.2	.1
CURVES	5	8	11	14

OUTPUT SECTION:

HUMIDITY CORRECTION FACTOR AND PERCENT RELATIVE HUMIDITY

BARO	KH	R
29.63	.765823	7.21505

MASS EMISSIONS IN GRAMS PER MILE

HC	CO	CO_2	NOXC
13.03	4.15	327.32	2.57

FUEL ECONOMY IN MILES PER GALLON 23.6569

READY

NAHBE I

Test 2

GENERAL ENVIRONMENTS CORPORATION

THREE BAG EXHAUST EMISSIONS ANALYSIS

VEHICLE NUMBER: 5332
RUN NUMBER: 440

DATE (M, D, Y): 1 19 77
TEST SEQUENCE NUMBER: 2

HUMIDITY CORRECTION FACTOR AND PERCENT RELATIVE HUMIDITY

PART	BARO	KH	R
1	*29.63*	*.76332*	*6.24909*
2	*29.63*	*.757648*	*4.74429*
3	*29.63*	*.759995*	*4.90154*

GRAMS PER TEST PHASE

PART	HC	CO	CO_2	NOX	NOXC
1	43.47	61.89	1610.48	18.52	14.14
2	33.42	35.48	2025.94	12.32	9.33
3	29.57	31.89	1497.61	13.6	10.34

1975 MASS EMISSIONS IN GRAMS PER MILE

HC	CO	CO_2	NOX	NOXC
9.2	10.7	476.28	3.74	2.84

1975 CALCULATED FUEL ECONOMY: 16.99 MPG

READY

NAHBE I
COMMUTER CYCLE
Test 2

GENERAL ENVIRONMENTS CORPORATION
HIGHWAY FUEL ECONOMY ANALYSIS

VEHICLE NUMBER: 5332
RUN NUMBER: 440

DATE (M, D, Y): 1 19 77
TEST SEQUENCE NUMBER: 2

INPUT DATA FEEDBACK

DELTA P	INDEP	REVS	TEMP
73	79.5	17775	116

BARO	WET BULB	DRY BULB
29.63	51.9	81.5

SAMPLE BAG:

	HC	CO	CO_2	NOX
DIVISIONS	71.4	71.9	38.1	56.8
CURVES	4	8	11	14

AIR BAG:

	HC	CO	CO_2	NOX
DIVISIONS	1	.7	1.1	0
CURVES	4	8	11	14

OUTPUT SECTION:

HUMIDITY CORRECTION FACTOR AND PERCENT RELATIVE HUMIDITY

BARO	KH	R
29.63	.764024	5.82637

MASS EMISSIONS IN GRAMS PER MILE

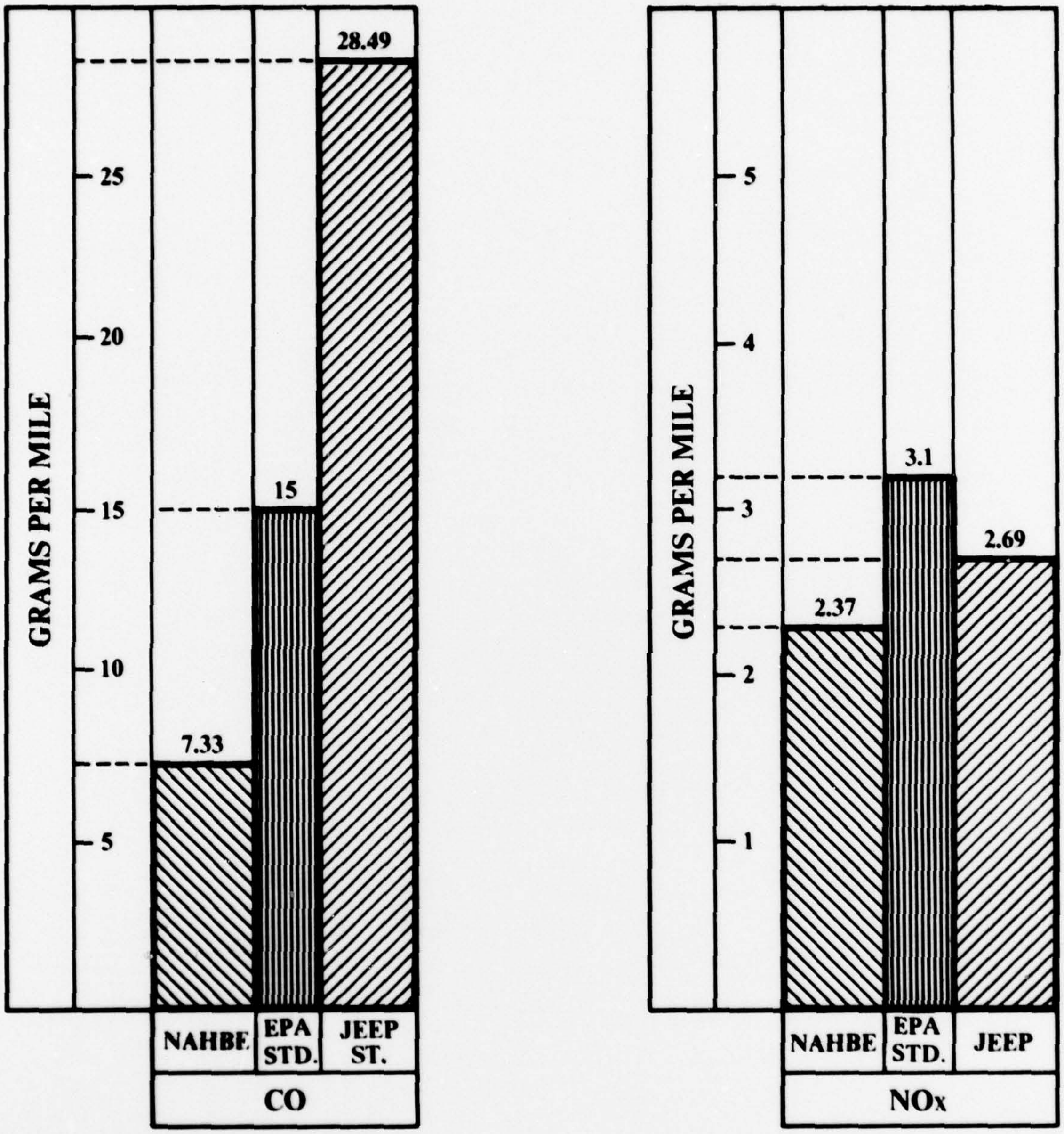
HC	CO	CO_2	NOXC
4.67	6.79	318.93	2.5

FUEL ECONOMY IN MILES PER GALLON 25.7697

READY

NAHBE I

EPA CERTIFICATION ANALYSIS
EMISSION – COMMUTER CYCLE*

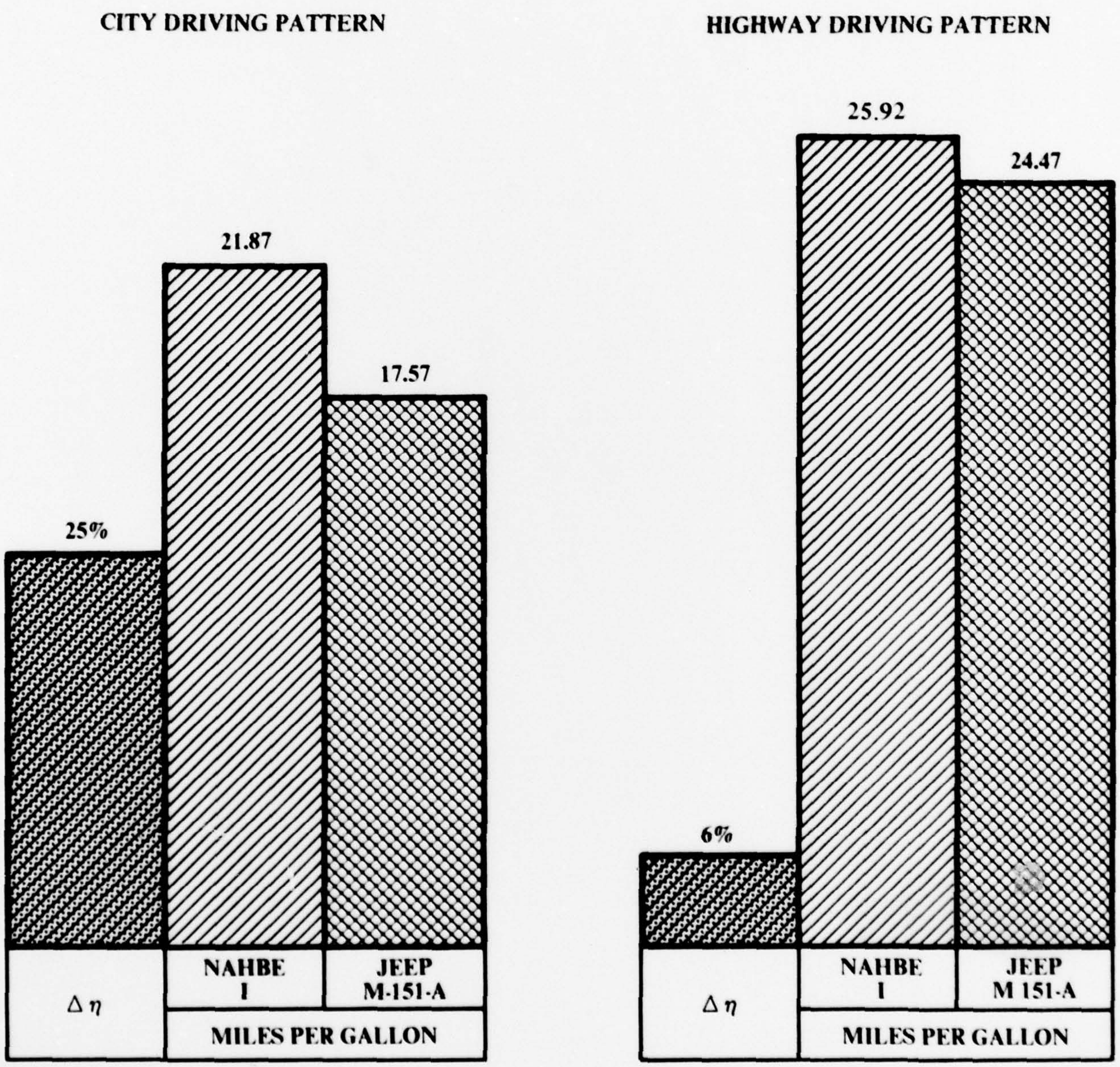


*DATA FROM
GENERAL ENVIRONMENT CORPORATION
SPRINGFIELD, VIRGINIA

EPA APPROVED LABORATORY
EPA STANDARD TESTING PROCEDURE

NAHBE I

EPA CERTIFICATION ANALYSIS
FUEL ECONOMY



$\Delta\eta$ = NAHBE IMPROVEMENT

NAHBE I FUTURE OF EXPECTATIONS

The 3,000 miles of normal continuous use of NAHBE I, the unquestionable reality of the applicability of the NAHBE mode of operation for the multicylinder spark ignited engine and the real achievement of the theoretical expectations during the operation and EPA certification of NAHBE I, sustain the projected forecast for the application of NAHBE technology in the control of national and worldwide challengers—"FUEL AVAILABILITY AND POLLUTION ABATEMENT.

FUEL AVAILABILITY

A case study published in *Lubrication* by Texaco in 1972, for projecting the effect of the introduction of the direct injection stratified charge (DISC) engine (Texaco combustion process) in the balancing of fuels for an average of 4.3 billion miles of our normal daily need of transportation will be used. Recalling that the capabilities of NAHBE for using fuels with a boiling range from 100° F. to 650° F., NAHBE can burn harvest fuels as alcohol or composite fuel as methacoal (a colloidal suspension of coal in methanol.) It is a realistic expectation that NAHBE offers equal or better solutions than DISC and fundamentally; in more than 10 years of developing, DISC vehicle capable of comparison with NAHBE I.

Case	Miles (kilometres) of Transportation per day x 10^9	Miles (kilometres) of Transportation per barrel (cubic metre) of crude	*Crude* — BPCD (m^3 PCD)** x 10^6*		
			Required	Produced in U.S. 1972	Deficiency or [Surplus]
A 96 RON Leaded	4.33 (6.97)	345 (3490)	12.56 (2.00)	11.22 (1.78)	1.34 (0.22)
B 91 RON Lead-free	4.33 (6.97)	325 (3290)	13 32 (2.12)	11.22 (1.78)	2.10 (0.34)
C Diesel	4.33 (6.97)	355 (3590)	12.20 (1.94)	11.22 (1.78)	0.98 (0.16)
D DISC	4.33 (6.97)	405 (4100)	10.69 (1.70)	11.22 (1.78)	[0.53 (0.08)]
E Future Concept	4.33 (6.97)	352 (3560)	12.30 (1.96)	11.22 (1.78)	1.08 (0.18)

* Crude as used here refers to crude oil, natural gas liquids, and certain gases.
** Barrels Per Calendar Day (Cubic Metres Per Calendar Day)

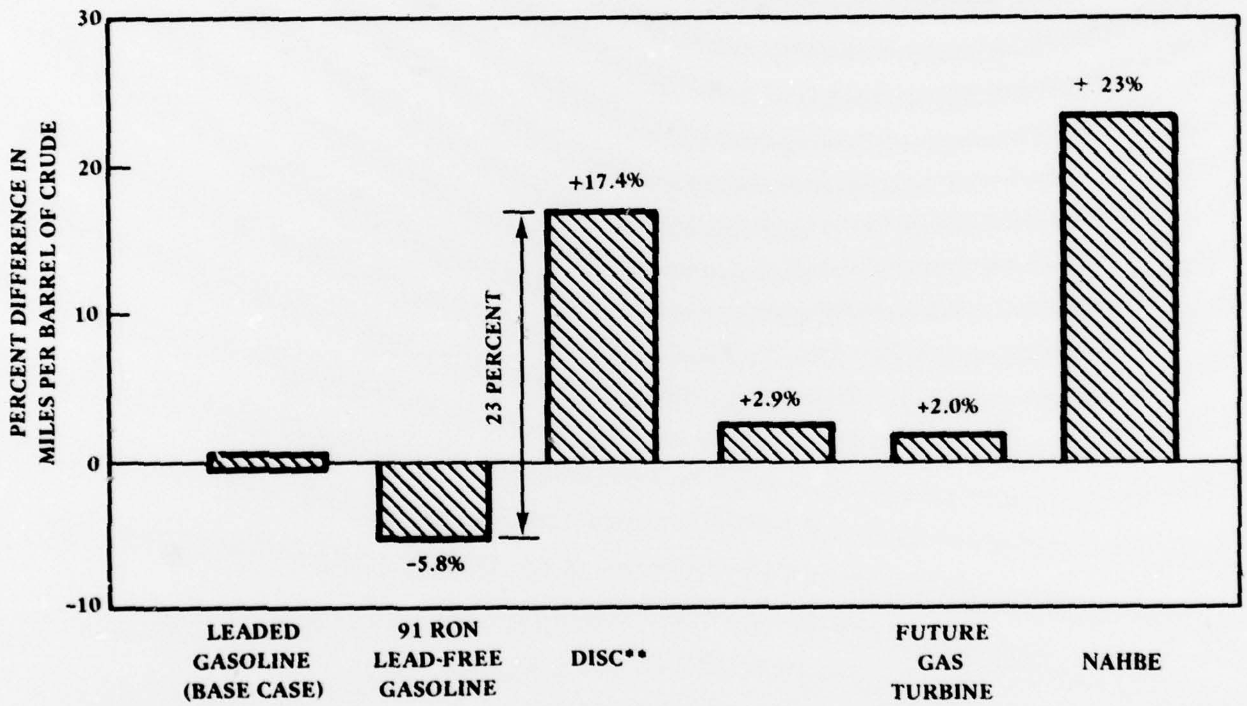
The maximum amount of crude was required when 91 RON lead-free gasoline production was maximized (See Table, Case B). This is the course being followed in the U.S. at the present time. New automobiles are equipped with catalytic converters to meet emission standards, and the petroleum industry is required to produce unleaded gasoline to protect the catalyst. Compared to the Base Case, not only was there a loss from 345 to 325 in miles (3490 to 3290 kilometers) of transportation attainable per barrel (cubic meter) of crude, but crude requirement also increased from 12.56 to 13.32 million barrels (2.00 to 2.12 million cubic meters) per day.

In contrast, an increase in transportation capability per barrel of crude can be obtained by producing maximum diesel fuel. However, it was not possible to eliminate the manufacture of gasoline using existing processing units to the maximum extent possible. Thus, the maximum ratio of diesel fuel to leaded gasoline was found to be about one to three. This is demonstrated in Case C, which shows a potential of 355 miles per barrel (3590 kilometers per cubic meter) of crude and a

crude requirement of 12.20 million barrels (1.94 million cubic meters) per day to maintain a total transportation capability of 4.33 billion miles (6.97 billion kilometers) per day.

The best transportation capability, however, occurs in Case D, which uses a DISC engine and a fuel that has a boiling range between 100° F (38°C) and 650° F (343° C). This engine has no octane or cetane requirements for satisfactory performance.

NAHBE I – FUEL AVAILABILITY PROJECTION

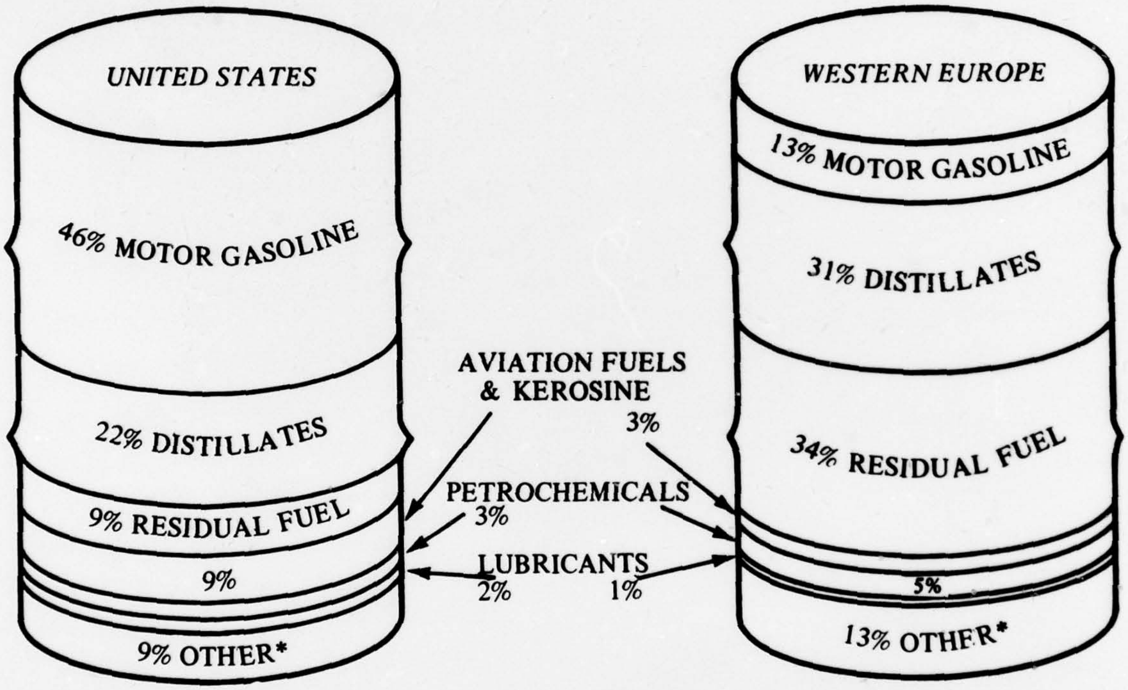


V-F-R* effects.

* VEHICLE FUEL REFINERY SYSTEM
** DIRECT INJECTION STRATIFIED CHARGE
*** NAHBE–NAVAL ACADEMY HEAT BALANCED ENG.

CRUDE REQUIREMENTS

(From *LUBRICATION*, published by Texaco, Inc.)



* INCLUDES ASPHALT, COKE, LPG, REFINERY GAS AND MISCELLANEOUS

Sources: Mineral Industry Surveys–U.S. Bureau of Mines, January, 1975; EEC Statistics–Quarterly Bulletin, 3rd Quarter 1975.

Representative distribution of products from a barrel of crude oil—1974

POLLUTION ABATEMENTS

For evaluating the economic impact of the implementation of NAHBE in the transportation industry, a publication in *Road and Track Magazine* "The Cost of Clean Air", is used for reference and the projected forecast is sustained by the results of EPA certification of NAHBE I. This first operative NAHBE vehicle started from a 1965, 30,000–mile, used Jeep, and has not required any of the pollution making devices today in use.

THE COST OF CLEAN AIR

"Unless there is a technical breakthrough of major proportions in the next few years, we're going to be paying a fortune for emission–controlled cars. We've heard estimates from the U. S. car industry of up to $500 per car to meet the 1976 federal standards, and remember that this figure is exclusive of the sum required to conform cars to the separate and distinct safety regulations.

Actually we're already paying the penalty; it isn't as heavy to meet the current standards, but it's noticeable in the purchase price, the performance of the engine, and the fuel consumption. The real crunch didn't come until 1971, or for most imported cars 1972. This was when the compression ratios came tumbling down to adapt engine to the 91-octane, leadfree gasoline.

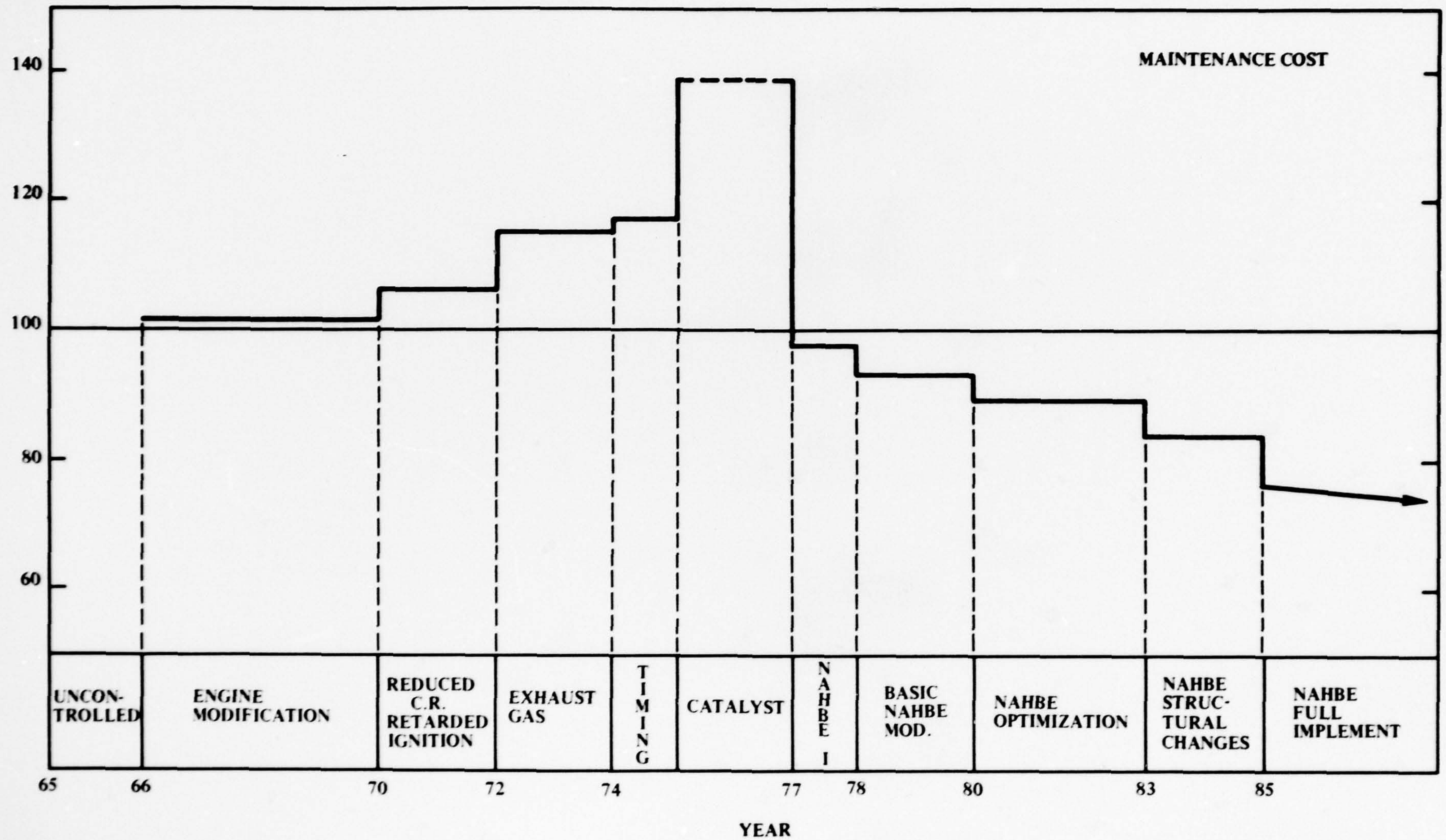
The 1972 situation finds fuel consumption up about 20%, power down 15% and service requirement (the dotted line) up 10%. In 1974 the fuel consumption will be up by 35%, power down by 18%. For 1975, when it's assumed the catalyst will be needed, the servicing requirement goes "off scale" –more money out of your pocket – and we get a little fuel economy back because the converter allows better engine settings to be used, while power goes down another step. Finally, by 1976 when the federal standards mandate a further reduction in nitrogen-oxide emissions, a more complex converter is required; power and economy take a final tumble. Then we'll be using 30% more fuel and getting 30% less peak power. The skyrocketed service requirement assumes periodic replacement of the converter.

–Reprinted from *Road and Track*.

NAHBE IMPLEMENTATION

ECONOMIC PROJECTION

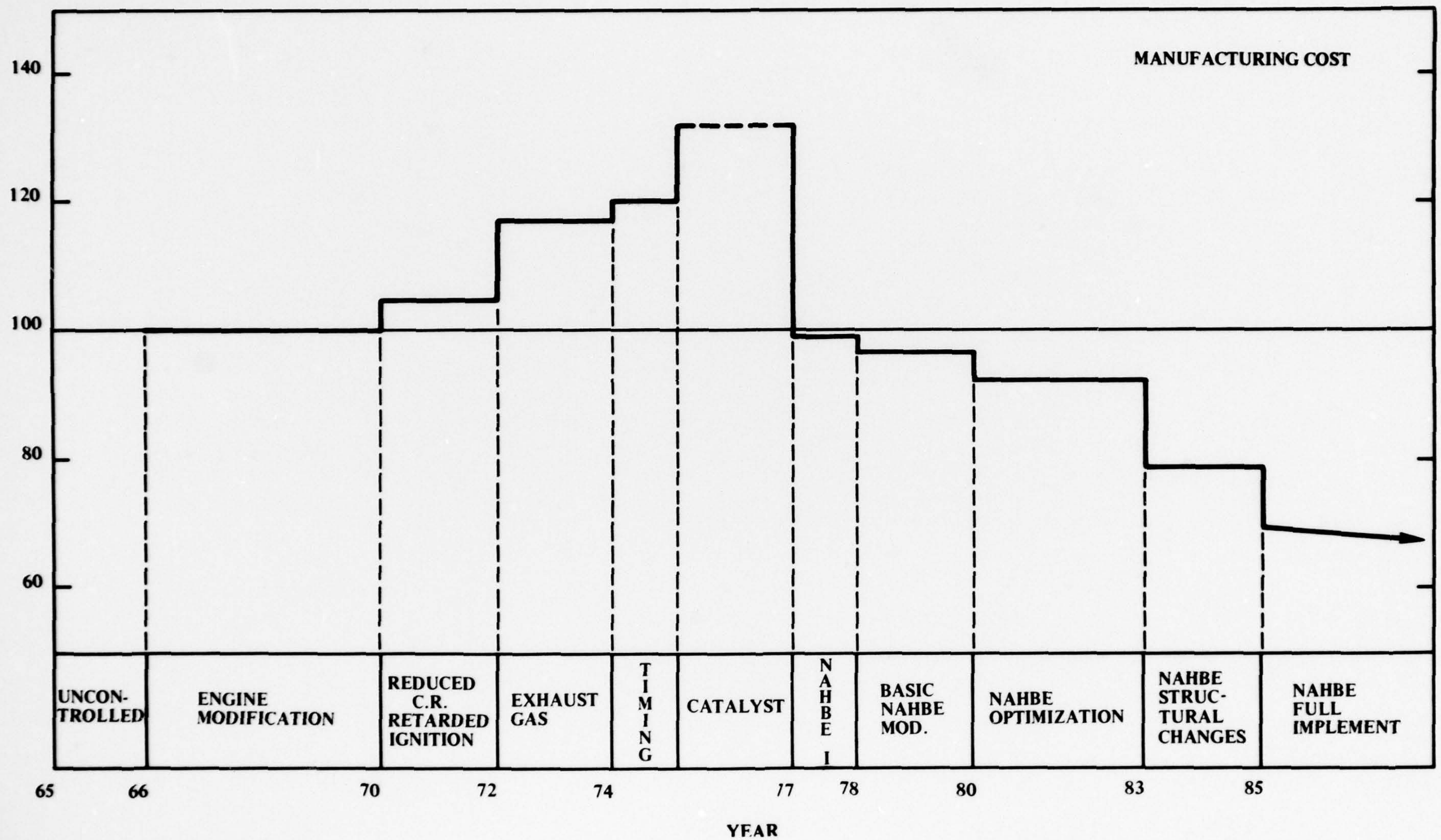
CHANGES OVER 1965 BASELINE



NAHBE IMPLEMENTATION

ECONOMIC PROJECTION

CHANGES OVER 1965 BASELINE



NAHBE IMPLEMENTATION

ECONOMIC PROJECTION

CHANGES OVER 1965 BASELINE